N10/4/CHEMI/HP3/ENG/TZ0/XX/M

International Baccalaureate®
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MARKSCHEME

November 2010

CHEMISTRY

Higher Level

Paper 3

21 pages

1. Follow the markscheme provided, award only whole marks and mark only in **RED**.

2. Where a mark is awarded, a tick/check (✓) **must** be placed in the text at the **precise point** where it becomes clear that the candidate deserves the mark. **One tick to be shown for each mark awarded.**

3. Sometimes, careful consideration is required to decide whether or not to award a mark. In these cases write a brief annotation to explain your decision. You are encouraged to write comments where it helps clarity, especially for moderation and re-marking. It should be remembered that the script may be returned to the candidate.

4. Unexplained symbols or personal codes/notations are unacceptable.

5. Record marks in the right-hand margin against each mark allocation shown in square brackets *e.g.* ***[2]***. The total mark for a question must equal the number of ticks for the question.

6. Do **not** circle sub-totals. **Circle the total mark** for the question in the right-hand margin **at the end of the question.**

7. Where an answer to a part question is worth no marks, put a zero in the right-hand margin next to the square bracket.

8. Where work is submitted on additional sheets the marks awarded should be shown as ticks and a note made to show that these marks have been transferred to the appropriate square bracket in the body of the script.

9. For each option: Add the totals for each question in the option and write it in the Examiner column on the front cover.
Total: Add the marks awarded and enter this in the box marked TOTAL in the Examiner column on the cover sheet.

10. After entering the marks on the front cover check your addition to ensure that you have not made an error. Check also that you have transferred the marks correctly to the cover sheet. **All scripts are checked and a note of all clerical errors will be given in feedback to examiners.**

11. If an answer extends over more than one page and no marks have been awarded on a section draw a diagonal line through that section to indicate that it has been marked.

12. If a candidate has attempted more than the required number of questions within a paper or section of a paper, mark all the answers and use the marks of those answers that have the highest mark, **unless the candidate has indicated the question(s) to be marked on the front cover**.

13. A mark should not be awarded where there is contradiction within an answer. Make a comment to this effect in the left hand margin.

Subject Details: Chemistry HL Paper 3 Markscheme

Mark Allocation

Candidates are required to answer questions from **TWO** of the options **[2 × 25 marks]**. Maximum total = **[50 marks]**.

1. A markscheme often has more marking points than the total allows. This is intentional. Do not award more than the maximum marks allowed for part of a question.

2. Each marking point has a separate line and the end is signified by means of a semicolon (;).

3. An alternative answer or wording is indicated in the markscheme by a slash (/) – either wording can be accepted.

4. Words in brackets ( ) in the markscheme are not necessary to gain the mark.

5. Words that are underlined are essential for the mark.

6. The order of marking points does not have to be as in the markscheme, unless stated otherwise.

7. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the markscheme then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by writing ***OWTTE*** (or words to that effect).

8. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

9. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. Indicate this with **ECF** (error carried forward).

10. Only consider units at the end of a calculation. Unless directed otherwise in the markscheme, unit errors should only be penalized once in the paper. Indicate this by writing **–1(U)** at the first point it occurs and **U** on the cover page.

11. Significant digits should only be considered in the final answer. Deduct **1 mark in the paper** for an **error of 2 or more digits** unless directed otherwise in the markscheme.

e.g. if the answer is 1.63:

2	*reject*
1.6	accept
1.63	accept
1.631	accept
1.6314	*reject*

Indicate the mark deduction by writing –**1(SD)** at the first point it occurs and **SD** on the cover page.

12. If a question specifically asks for the name of a substance, do not award a mark for a correct formula, similarly, if the formula is specifically asked for, do not award a mark for a correct name.

13. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the markscheme.

14. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the markscheme.

Option A — Modern analytical chemistry

A1. (a) determination of structure
determination of concentrations
identification of substances
Allow separation of substances.

analysis of (different) composition of substances/compounds/mixtures
determination of purity of substances
in medicine for body imaging
Do not allow just in medicine.

determining illegal drug use
forensic science for evidence in courts
monitoring of the environment
DNA testing
testing foods for levels of sugar/testing quality of food ***[1]***
Accept other specific examples.
Do not award mark for repeating examples given in (b).
*Award **[1]** for any two.*

(b) (i) gas-liquid chromatography/GLC/high-performance liquid chromatography/ HPLC / gas-chromatography-mass spectrometry/GC-MS; ***[1]***
Allow gas-chromatography/GC.
Do not award mark for stating chromatography alone.

(ii) MS/mass spectrometry/spectroscopy; ***[1]***

(iii) (^{1}H/proton) NMR/nuclear magnetic resonance / MRI/magnetic resonance imaging; ***[1]***

A2. (a) (using a rotating mirror) beam of monochromatic radiation / radiation of one frequency/wavelength/wavenumber;
splitter splits (IR) light into two beams (of same wavelength);
which passes through sample **and** reference;
photomultiplier converts radiation/photons into current/signal/voltage (output) / photomultiplier/photodiode used as detector;
absorbance/transmittance of reference compared with/subtracted from absorbance/transmittance of sample / reference used to set baseline / *OWTTE*;
IR spectrum generated by varying wavelength/frequency/wavenumber / *OWTTE*; ***[3 max]***
Accept correctly labelled diagram including these points.

(b) change in bond length / bond stretching / asymmetric stretch;
change in bond angle / bending (of molecule);
*Allow **[1 max]** for only stating vibrations.*

induces molecular polarity/dipole moment / *OWTTE*; ***[3]***

(c) (i) **A**: C–H
B: C=O
C: C–O ***[2]***
*Award **[2]** for three correct, **[1]** for two correct.*

(ii) $m/z = 31 : CH_3O^+$;
$m/z = 29 : HCO^+$; ***[2]***
Penalize missing + charge once only.
Elements can be given in any order (i.e. OCH_3^+, COH^+, CHO^+).

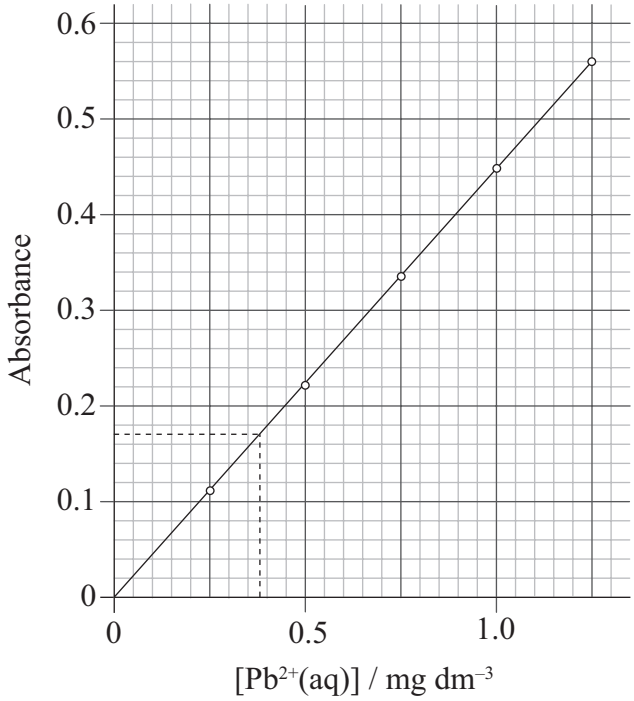
(iii) 3.76 ppm : CH_3O **and** 8.07 ppm : HCO ; ***[1]***
Allow CH_3 for CH_3O.
Allow $RCOOCH_2$ and $RCOOCH_3$ for 3.76 ppm and RCHO for 8.07 ppm.

(iv) three hydrogens in same environment; ***[1]***
Allow three times as many hydrogens in this environment as for the other peak.

(v) HCO_2CH_3 / $HCOOCH_3$; ***[1]***

(vi) all (12) protons/hydrogens in same chemical environment (and hence gives 1 peak);
absorbs upfield/away from most other protons/H's;
low boiling point/bp / volatile / easily removed from sample;
not toxic;
highly unreactive (and hence does not interfere with sample) / inert; ***[2 max]***

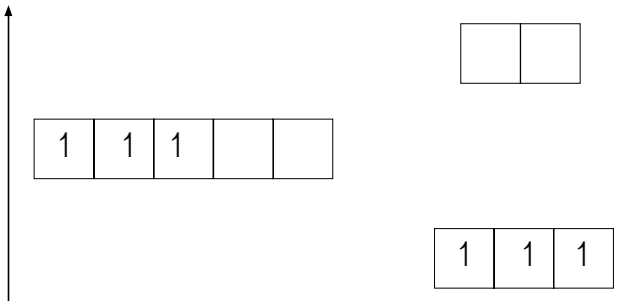
A3. (a) graph of absorbance versus concentration showing all five points plotted **and** connected;
Do not penalize if graph is not extended to origin.
Points should be plotted closest to within one-half of a small square.



determination of concentration $(\sim 0.38\ \text{mg dm}^{-3})$ corresponding to absorbance of 0.170 ;
Allow a range of 0.35 to 0.42.

concentration not within/more than WHO limit / *OWTTE*; ***[3]***

(b) (i)



; ***[1]***

(ii) increases / greater;

*Award **[1]** for one of the following:*
NH_3 has greater electron/charge density;
NH_3 higher in spectrochemical series;
NH_3 stronger base; ***[2 max]***
Allow converse argument for H_2O.
Do not award M2 for stating that NH_3 is a stronger ligand or has a smaller size.
If decreases is given for M1, then M2 cannot be scored.

Option B — Human biochemistry

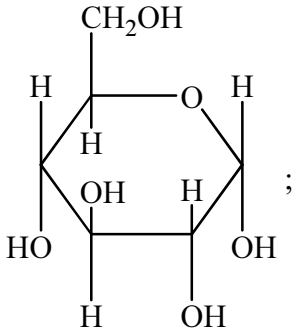
B1. (a) $\Delta T = 7.35\,(\text{K}/^{\circ}\text{C})$;

$q\,(= mc\Delta T = 200.10\text{ g} \times 4.18\text{ J g}^{-1}\text{ K}^{-1} \times 7.35\text{ K}) = 6.15 \times 10^{3}\text{ J}$ (per 0.85 g of glucose heated);

energy value $= 7.2 \times 10^{3}\,(\text{J g}^{-1})$; ***[3]***

*Award **[3]** for correct final answer.*

(b) (i)



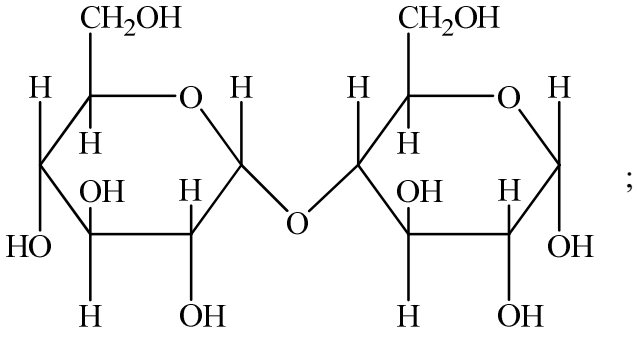
;

[1]

Accept CH_2OH and OH groups on either face, as long as OH on C3 is on the opposite face to the OH's on C1, C2 and C4.

No mark awarded if $HOCH_2$ is written, with H bonded to C or if HO is written for hydroxyl groups, with H bonded to C. Penalize this once only in (i) and (ii).

(ii)



;

[1]

B2. (a) 2 mol of iodine reacts with 1 mol of linoleic acid;
$M_r = 253.80$ g mol^{-1} for iodine **and** $M_r = 280.50$ g mol^{-1} for linoleic acid;
$\left(\frac{(507.60 \times 100.00)}{280.50} = \right) 180.96\,(g) / 181\,(g)$; ***[3]***
*Award **[3]** for correct final answer.*
Allow 254 g mol^{-1} for iodine and 281/280 g mol^{-1} for linoleic acid.
*Award **[2 max]** for incorrect ratio calculation to give answers such as 90.4, 90.481, 90.7 (g) depending on M_r values used.*

(b) less oxidized (compared to carbohydrates) / fewer oxygen atoms (compared to carbohydrates); ***[1]***

(c) C=C's in linoleic acid cause the chain to be more uneven/kinked;
linoleic acid cannot pack as closely as stearic acid;
intermolecular/van der Waal's/London/dispersion forces weaker in linoleic acid; ***[2 max]***
Accept converse argument for stearic acid.

B3. (a) (i) alkene;
ketone; ***[2]***
Accept carbonyl.

(ii) 21; ***[1]***

(b) treating hormone disorders;
treating testes / increase sperm production;
treating breast cancer;
induce male puberty;
gain weight / building tissue (following illness);
sex change to male;
[2 max]

B4. (a) (i) bases;
(held together by) hydrogen bonds;
Allow named bases ***[2]***

(ii) coded information lies in sequence of bases;
each sequence of three bases represents one amino acid/triplet code;
allows for up to 64 permutations / codons;
represents 20 naturally occurring amino acids;
human genome / complete sequence of bases in human DNA; ***[3 max]***

(b) *Steps*: ***[3 max]***
DNA extracted / *OWTTE*;
amount of DNA multiplied / amplified (by use of PCR);
(broken down using) restriction enzymes;
into smaller fragments called minisatellites;
splits occur in minisatellites in areas where there are no codons;
(fragments into bands using) (gel) electrophoresis;
labelling with radioactive phosphorus;
X-ray film to detect radiation;
fingerprint of all fragments obtained;

Uses: ***[1 max]***
solution of criminal cases;
paternity cases;
mapping of evolutionary tree of species;
identification of genetic illnesses;
human genome project; ***[4 max]***
Award ***[1 max]*** *for any two.*

Option C — Chemistry in industry and technology

C1. *Arguments for*: ***[2 max]***
high energy content / high enthalpy of combustion;
shortage of alternatives;
alternatives are expensive / oil relatively cheap;
well-established technology;
easy to store;
easy to transport;
produces energy at a reasonable rate;

Arguments against: ***[2 max]***
chemical feedstock of limited supply/*OWTTE;*
non-renewable;
combustion causes global warming / greenhouse gases;
combustion produces acidic gases; ***[4]***
Apply / OWTTE throughout.

C2. steam cracking;
$C_6H_{14} \rightarrow C_3H_8 + C_3H_6$; ***[2]***
Ignore state symbols.

C3. (a) nanotechnology involves research and technology developments at the 1 nm to 100 nm range;
structures with novel properties (because of their small size) / *OWTTE*;
ability to manipulate on the atomic scale / *OWTTE*; ***[2 max]***
Overlap here between definition and matters of interest, so accept any two.

(b) (main) cylinder consists of (carbon) hexagons / *OWTTE*;
pentagons close structures/tubes at ends / *OWTTE*; ***[2]***
Marks may also be scored by means of a suitable diagram showing above.

(c) health concerns / concern that the human immune system will be defenceless against particles on the nanoscale;
potential toxicity of materials / toxicity regulations are difficult (to apply);
possible explosive nature of large scale manufacture of nanoparticles;
political issues; ***[2 max]***
Apply / OWTTE throughout.

C4. (a) *Negative electrode (anode)*:
$H_2(g) + 2OH^-(aq) \rightarrow 2H_2O(l) + 2e^-$;

Positive electrode (cathode):
$H_2O(l) + \frac{1}{2}O_2(g) + 2e^- \rightarrow 2OH^-(aq)$; ***[2]***

Allow correct equations involving multiple coefficients (i.e. $2H_2$ etc.)
Ignore state symbols.
Allow e instead of e^-.
*Award **[1 max]** for correct equations but at incorrect electrodes.*

(b) lithium-ion; ***[1]***

C5. (a) (i) (organic) fluoropolymer / fluorinated polymer / PTFE / polytetrafluoroethylene / polytetrafluoroethene; ***[1]***

(ii) titanium / inert/non-reactive metal; ***[1]***

(iii) $Cl^-(aq) \rightarrow \frac{1}{2}Cl_2(g) + e^-$; ***[1]***
Allow correct equations involving multiple coefficients (i.e. $2Cl^-(aq)$ etc.)
Ignore state symbols.
Allow e instead of e^-.

(b) (membrane cell) cheaper to construct;
(membrane cell) cheaper to operate;
(membrane cell) does not use toxic materials / mercury and asbestos;
sodium hydroxide solution produced more pure than that of diaphragm cell; ***[4]***

(c) feedstock for chemical industry;
paper manufacture;
production of aluminium;
manufacture of soap;
cleaning drains; ***[3 max]***

Option D — Medicines and drugs

D1. (a) hydrochloric acid; ***[1]***

(b) $Al(OH)_3 + 3HCl \rightarrow AlCl_3 + 3H_2O$;
$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$; ***[2]***
Ignore state symbols.
*Award **[1 max]** for correct reactants and products in both equations if equations are not balanced.*

(c) (i) neutralizes excess stomach acid / produces neutralizing layer;
prevents acid in stomach from rising / prevents acid reflux; ***[2]***

(ii) prevent flatulence/(stomach) bloating / *OWTTE*;
dimethicone / polydimethylsiloxane / PDMS; ***[2]***

D2. (a) *Advantage*: ***[1 max]***
does not affect stomach / ulceration/bleeding;
does not give allergic reactions;
does not give Reye's syndrome;

Disadvantage: ***[1 max]***
causes blood disorders;
causes kidney damage;
liver damage;
brain damage;
not an anti-inflammatory; ***[2 max]***

(b) (i) amine;
ether;
alkene;
benzene ring; ***[2 max]***
Do not allow arene.
Allow phenyl (ring or group) or benzene.
Allow structural representation of functional group instead of name (e.g. C=C instead of alkene).

(ii) phenol / alcohol / hydroxyl (group); ***[1]***
Allow OH.

(iii) (di)esterification / condensation / (di)acetylation; ***[1]***

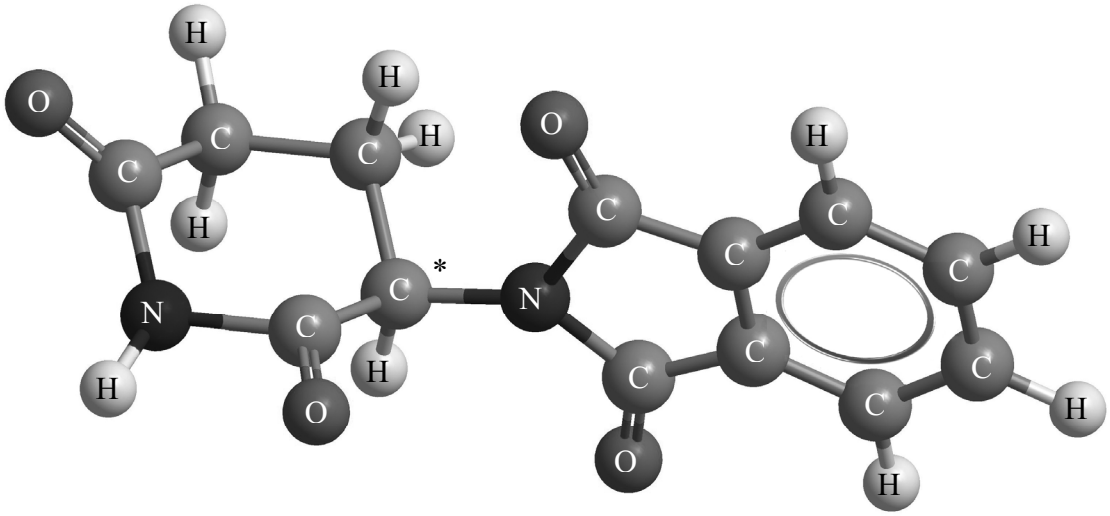
D3. (a) *Increased potency of diamorphine compared to morphine*:
polarity / polar hydroxyl groups in morphine replaced by non-polar ester groups in diamorphine;

Penicillin:
ring strain;

Cisplatin:
geometrical isomerism; ***[3]***
Allow isomerism for M3 (since geometrical given in question).

(b) ring opens (to allow penicillin to bond to enzyme);
which synthesizes bacterial cell walls and so blocks action / prevent cell wall / membrane formation; ***[2]***

(c) (i)



chiral centre marked * on structure; ***[1]***

(ii) one alleviates morning sickness in pregnant women;
other causes deformities in limbs of fetus / birth defects;
OR
drug racemises in blood / *OWTTE*;
both isomers could form deformities / *OWTTE*; ***[2 max]***

D4. *Structural similarities*:
aromatic/benzene ring;
Do not allow arene.

indole / heterocyclic ring;

amine;
Ignore any reference to classification of amine (even if incorrect).
Allow diagrammatic representations of relevant groups, rings.

Effect:
hallucinogenic / alteration of perception / distortion of senses / *OWTTE*; ***[4]***

Option E — Environmental chemistry

E1. (a) CO;
NO;
Accept NO_x / NO_2
VOCs / volatile organic compounds / unburned hydrocarbons;
particulates / carbon; ***[3 max]***
Accept names.

(b) $2CO + 2NO \rightarrow 2CO_2 + N_2$ / $CO + NO \rightarrow CO_2 + \frac{1}{2}N_2$ / $2CO + O_2 \rightarrow 2CO_2$ / $CO + \frac{1}{2}O_2 \rightarrow CO_2$; ***[1]***
Ignore state symbols.

(c)

Pollutant	Effect
Carbon dioxide	*Contributes to global warming*
CO	toxic / prevents haemoglobin from transporting oxygen;
NO_x	toxic / smog / acid deposition/rain;
VOCs	smog / forms (toxic) PANs/peroxyacylnitrates;
Particulates	smog / respiratory problems / lung diseases / carcinogenic/cancer-causing;

More specific lung diseases may be given e.g. emphysema, bronchitis etc.

E2. *Source*:
power stations / (cooling processes in) industry/factory;

Effect:
lowers oxygen solubility / *OWTTE*;

Result:
less oxygen for fish / fish harmed/die; ***[3]***
Accept increased need for oxygen because of increased metabolism.

E3. (a) (i) substances that plants need for growth; ***[1]***

(ii) harvesting of crops (removes nutrients);
(nutrients replaced) by compost/(artificial) fertilizer; ***[2]***
Accept loss of nutrients through irrigation/soil loss/acidification through addition of fertilizer.

(b) CEC tends to decrease;
H^+ / Al^{3+} released/*OWTTE*;
Mg^{2+} lost (so no longer available to plants); ***[3]***
Allow reference to metals instead of their ions.

E4. (a) (i) shorter wavelength / higher energy radiation / UV is needed to break the bond in O_2;
because O_2 has double/stronger bond; ***[2]***
Accept converse argument for O_3.

(ii) *Formation of ozone*:
$O_2 \rightarrow 2O\bullet$ **and** $O_2 + O\bullet \rightarrow O_3$;

Depletion of ozone:
$O_3 \rightarrow O_2 + O\bullet$ / $O_3 + O\bullet \rightarrow 2O_2$; ***[2]***
Ignore state symbols.
Allow radical representation without dot throughout.
Do not allow inconsistent use of dot symbol.

(b) (i) $CCl_2F_2 \rightarrow CClF_2\bullet + Cl\bullet$;
$Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$;
$ClO\bullet \rightarrow Cl\bullet + O\bullet$;
$ClO\bullet + O\bullet \rightarrow O_2 + Cl\bullet$ / $ClO\bullet + O_3 \rightarrow 2O_2 + Cl\bullet$; ***[3 max]***
Ignore state symbols.
Allow radical representation without dot throughout.
Do not allow inconsistent use of dot symbol.

(ii) $Cl\bullet$/ Cl regenerated / *OWTTE*;
can deplete further ozone molecules / catalytic / *OWTTE*; ***[2]***

Option F — Food chemistry

F1. (incorrect) water content
chemical/pH change
light
temperature
contact with air / oxygen
bacterial / fungal degradation / microbial spoilage ***[2 max]***
*Award **[2]** for four correct, award **[1]** for three or two correct.*

F2. (a) *Dye*:
synthetic (water-soluble) colourant;

Pigment:
naturally occurring colourant; ***[2]***

(b) (i) red / orange / yellow absorbed;
blue/complementary colour transmitted; ***[2]***
*Award **[1 max]** for all colours other than blue absorbed.*

(ii) strawberries;
raspberries;
cranberries;
bilberries;
chokeberries;
blackberries;
blackcurrants;
cherries;
(red) plums;
(red) grapes; ***[2 max]***
Accept other correct answers, but do not accept answers which are not fruits (e.g. beetroot, red-cabbage, flowers etc.)

(iii) low pH **and** low temperature; ***[1]***

(c) (i) extended delocalized system/delocalization/conjugated double bonds; ***[1]***

(ii) *Chromophore*:
(unsaturated) chemical group attached to molecule that affects frequency/ fragment of molecule responsible for colour which occurs when it absorbs certain wavelengths of visible light / *OWTTE*;

in structure shown, varying (chromophore) groups attached to benzene rings / delocalized system will change colour / (in anthocyanins) the (R–) groups that vary are –OH and $-OCH_3$; ***[2]***

F3. emulsifiers act as interface / surface between (liquid, solid and gas) phases in dispersed system;
are soluble in both fats **and** water / can bond to both fats **and** water; ***[2]***

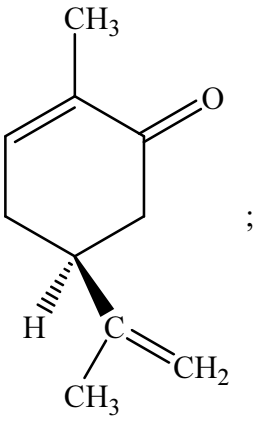
F4. (a) (i) contains –OH groups;
condensation / esterification; ***[2]***

(ii) contains –OH groups; ***[1]***

(b) to give olestra properties / melting point similar to those of cooking fats / if they were not smaller then olestra would have much higher melting point / very different properties than other cooking fats / *OWTTE*; ***[1]***

F5. (a) *Name*:
+(*d*)-carvone/s-carvone/(+)-(S)-carvone / dextro-carvone;

Structure:



;

[2]

(b) asymmetric / chiral carbon / *OWTTE*; ***[1]***

(c) +(*d*)-carvone tastes of caraway (seeds) **and** dill;
–(*l*)-carvone tastes of spearmint; ***[2]***

(d) –(*l*):
rotation of <u>plane</u> polarized light counter/anti-clockwise;

(*R*):
gives absolute configuration of groups around chiral carbon;
Allow enantiomer's spatial configuration for (R).
Priority groups (according to atomic number) ordered clockwise (according to Cahn-Ingold-Prelog convention). ***[2]***

Option G — Further organic chemistry

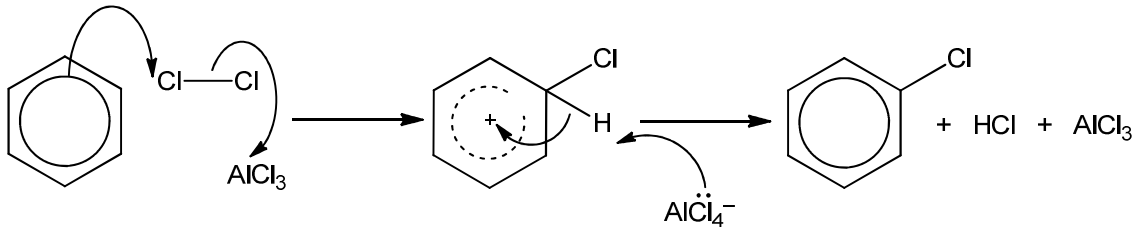
G1. (a) hexagonal / ring of six carbon atoms (each with one hydrogen);
planar;
all carbon-carbon bond lengths equivalent / all carbon-carbon bond lengths intermediate between single and double bonds/carbon-carbon bond order of 1.5;
all C–C–C bond angles 120°;
Allow sp^2 (hybridization for C's).

delocalization / resonance; ***[3 max]***

(b) enthalpy change of hydrogenation not equal to three times enthalpy change of hydrogenation of cyclohexene;
electron density map (of benzene) showing equal electron density / all carbon-carbon bond lengths equivalent/*OWTTE*;
Allow diffraction pattern or contour map for electron density map.

only one isomer exists for 1,2-disubstituted benzene compounds / only three disubstituted benzene compounds (rather than four);
undergoes (electrophilic) substitution reactions/does not undergo addition reactions/ does not decolorize bromine water; ***[2 max]***

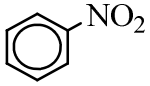
(c)



curly arrow going from delocalized electrons in benzene to Cl in Cl_2 **and** curly arrow going from Cl–Cl bond to $AlCl_3$;
Do not penalize if curly arrow originates inside circle.
Allow curly arrow going from delocalized electrons in benzene to Cl^+ for M1.

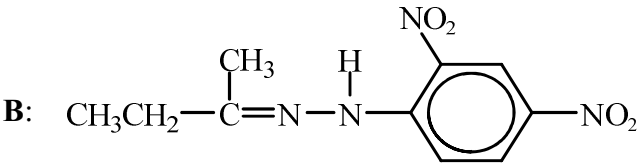
representation of carbocation with correct formula **and** positive charge on ring;
curly arrow going from lone pair/negative charge on Cl in $AlCl_4^-$ to H **and** curly arrow going from CH bond to benzene ring;
Allow $H^+ + AlCl_4^- \rightarrow HCl + AlCl_3$ as alternative to curly arrow going from lone pair/negative charge on Cl in $AlCl_4^-$ to H.

formation of organic product chlorobenzene **and** HCl **and** $AlCl_3$; ***[4]***
Allow other suitable catalysts such as $FeCl_3$ etc.
Allow mechanism with corresponding Kekulé structures.

(d) nitrobenzene / $C_6H_5NO_2$ /  ; ***[1]***

Accept multiple substitution products.

G2. (a) **A**: $CH_3CH_2CH(CH_3)Br$; ***[1]***

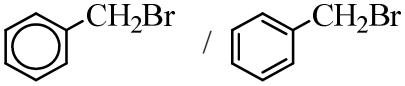
(b) **B**:  ; ***[1]***

(c) **C**: $(CH_3)_2C(OH)CN$; ***[1]***

(d) **D**: $CH_3CH_2(OH)C(CH_2CH_2CH_3)CH_3$; ***[1]***

More detailed structural formulas in each case may be given.
Penalize incorrect bonds (e.g. CN–C, OH–C) once only in (a)–(d).

G3. (a) <u>concentrated</u> phosphoric acid/ H_3PO_4 /sulfuric acid/ H_2SO_4;
$(CH_3)CH{=}CH_2$;
Br_2 /bromine;
$BrCH_2CHBrCH_3$; ***[4]***

(b) (addition of) Br_2 / bromine **and** UV light/*hf*/*hv*;
(addition of) Br_2 / bromine **and** $AlBr_3$ / aluminium bromide / $AlCl_3$ /aluminium chloride;
Allow other suitable catalysts such as $FeBr_3$ etc.
structure of first product
i.e.  ; ***[3]***
Order of steps does not matter (so first product could form 2-bromomethylbenzene).

G4. (a) $CH_3CONHCH_2CH_3$;
$CH_3CH_2NH_3^+Cl^-$ / $CH_3CH_2NH_3Cl$; ***[2]***
*Order of **E** and **F** does not matter.*

(b) $CH_3CH_2NH_2$ / ethylamine; ***[1]***

(c) addition-elimination; ***[1]***
Accept acylation.